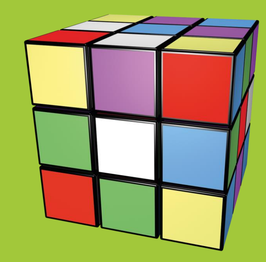
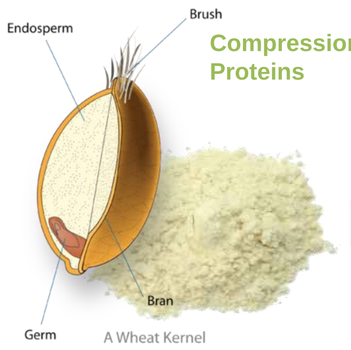
Wheat Gluten-Thermoplastic Polymer Blends With Improved Toughness

Thomas Langstraat[1], Alican Gençer[1], Bart Goderis[1]

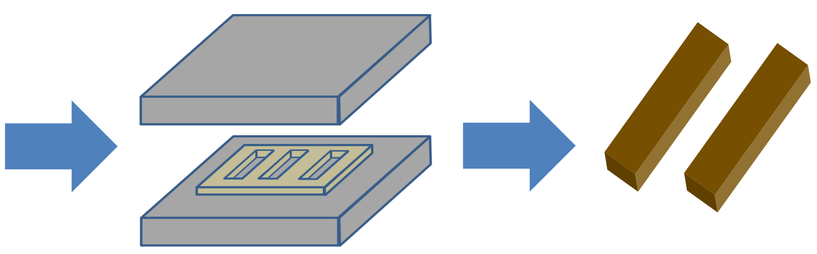
[1]Department of Chemistry, Polymer Chemistry and Materials, KULeuven, Celestijnenlaan 200F, 3001 Heverlee, Belgium



Introduction

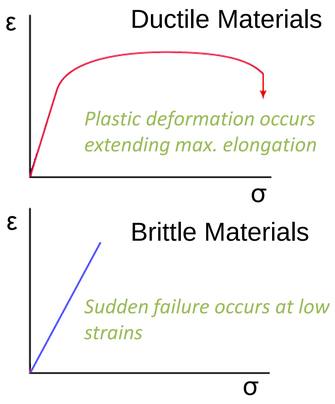


Compression Moulding Gluten Proteins

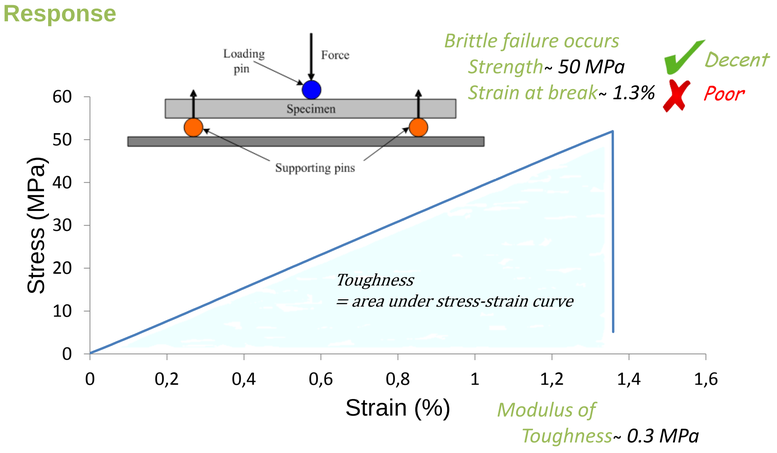


Gluten Powder (moisture; 6-9%) → 150 ˚C, 5 min → Rigid Thermoset

Typical Stress-Strain Responses



Gluten – 3 Point Bending Response



Brittle failure occurs
Strength~ 50 MPa
Strain at break~ 1.3%
✔ *Decent*
✘ *Poor*

Modulus of Toughness~ 0.3 MPa

Experimental

In order to improve material toughness gluten was blended with a thermoplastic polymer (TPP)

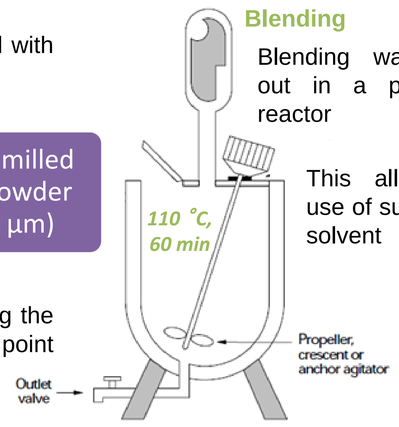
Components mixed in 70% Ethanol → Solvent removed under vacuum → Blend milled to a powder (250 µm)

Plastic specimens were prepared via compression moulding the powdered blends (150 ˚C, 5 min). Samples were tested in 3 point bending.

Blending

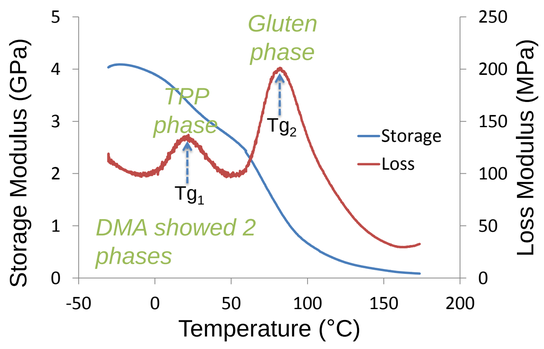
Blending was carried out in a pressurised reactor

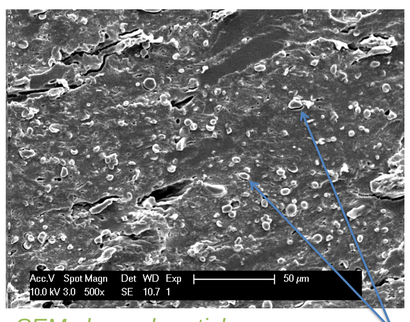
This allowed the use of superheated solvent



Blends

Morphology





5w% TPP

SEM showed particles in a matrix

Particles appear loose from matrix
→ *poor adhesion at interface*

Mechanical Properties

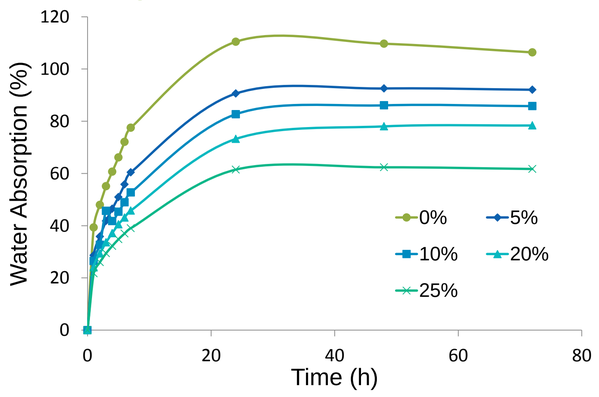
W% TPP	Modulus (GPa)	Strength (MPa)	Strain (%)
Reference	3.7 (0.2)	34.9 (4.6)	0.9 (0.1)
5	3.7 (0.0)	40.2 (2.1)	1.2 (0.1)
10	3.0 (0.1)	45.7 (2.0)	1.6 (0.1)
20	2.6 (0.2)	42.6 (2.4)	1.7 (0.0)
25	1.8 (0.1)	31.6 (1.7)	2.4 (0.2)

The blending conditions had an adverse effect on gluten mechanical properties (see reference).

Low addition (< 10%) of TPP increased both strength and strain. Higher w% of TPP further increased max. strain but was accompanied by a lowering of the modulus.

Material toughness was not improved compared to untreated gluten.

Water Absorption



The resistance to water absorption of gluten plastics improved upon blending with TPP.

Compatibiliser

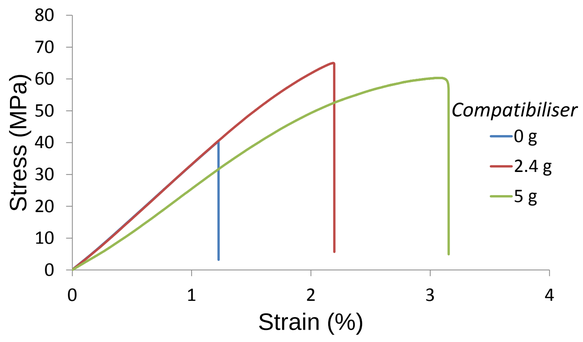
In order to improve adhesion between the gluten and TPP phases a difunctional compatibiliser was introduced during blending.

Mechanical Properties

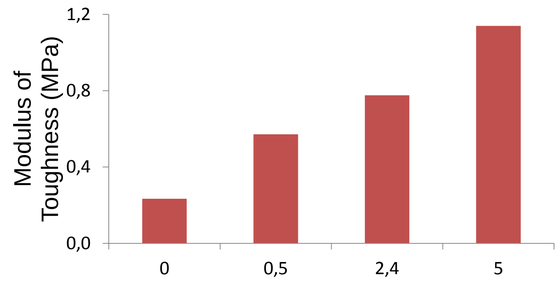
5w% TPP

Compatibiliser (g)	Modulus (GPa)	Strength (MPa)	Strain (%)
0	3.7 (0.0)	40.2 (2.1)	1.2 (0.1)
0.5	3.5 (0.1)	59.1 (1.0)	1.8 (0.0)
2.4	3.2 (0.1)	63.9 (1.8)	2.2 (0.1)
5	2.6 (0.2)	60.1 (1.7)	3.1 (0.1)
10	2.6 (0.1)	58.9 (2.4)	2.7 (0.2)

With the addition of compatibiliser mechanical properties were significantly improved



The stress-strain response started to show some non-linear behaviour
→ *Indicative of plastic deformation before failure*



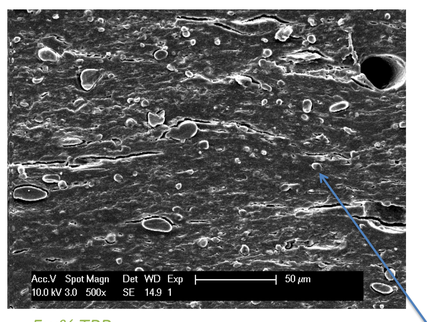
Toughness increased by more than a factor of 3

At both 5 & 10w% TPP, low addition of compatibiliser (0.5 g) did not affect material modulus. Higher levels of the compatibiliser appears to have a plasticising effect as modulus is lowered.

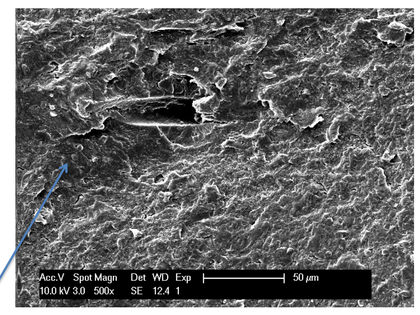
10w% TPP

Compatibiliser (g)	Modulus (GPa)	Strength (MPa)	Strain (%)
0	2.9 (0.1)	44.2 (1.5)	1.7 (0.1)
0.5	3.0 (0.1)	55.6 (2.6)	2.1 (0.1)
2.4	2.7 (0.0)	56.5 (2.5)	2.6 (0.1)
5	2.2 (0.1)	49.6 (1.1)	3.1 (0.1)

Morphology



5w% TPP
0.5 g compatibiliser



5w% TPP
2.4 g compatibiliser

Particles were more difficult to visualise by SEM as addition of compatibiliser was increased.
→ *Better adhesion between phases may result in more embedded particles*

Conclusions

- Rigid wheat gluten based plastics undergo brittle failure at low strains (1 – 1.5%) when subjected to mechanical stress.
- Blending with a thermoplastic polymer in combination with a compatibiliser can give specimens with improved elongation without comprising on material strength.
- At 5 – 10w% of TPP a two phase ‘particle in matrix’ morphology results.
- Compatibiliser appears to increase particle/matrix adhesion which results in an increased material toughness

References

1. Taylor, J.; Anyango, J. O.; Taylor, J. R. N. Cereal Chem 2013, 90, 344-357
2. Sionkowska, A. Prog Polym Sci 2011, 36, 1254-1276
3. Multicomponent Polymer Systems, *Advances in Chemistry Series 99,* 1971

agentschap voor Innovatie door Wetenschap en Technologie